Amendments to the Title Page:

Please amend theNote on "Related Patent Application" as follows:

RELATED PATENT APPLICATION

This application is related to US Patent Application Serial No. 10/764920 filed concurrently herewith on Jan. 26, 2004 and US Patent Application Serial No. 10/676919 filed Oct. 1, 2003, now issued as US Patent 6,937,098, and assigned to the same assignee as the present invention.

Amendments to the Specification:

In the SUMMARY OF THE INVENTION,
please replace the 2nd full paragraph on page 7 with the following amended paragraph:

Additional circuit elements, described in the related US Patent Application, Serial No. 10/676919, filed Oct. 1, 2003, titled "Translinear Amplifier" and hereby incorporated by reference, implement a signal cutoff function by providing a signal to sharply cut off said translinear amplifier's linear operation, once the defined linear operating range is exceeded at the negative end of said linear operating range; and to sharply limit said translinear amplifier's linear operation, once the linear operating range is exceeded at the positive end of said linear operating range. The circuits of said signal cutoff functions then either ~~overdrive~~ takes over control of said switching transistor to either drive it into deep saturation (RDSon going to 0) or ~~overdrive it~~ drive it into its extreme off

state (RDSoff going very high), when said switching device operates outside its desired steady transition phase.

Please replace the first paragraph on page 8 with the following amended paragraph:

The total concept according to the proposed invention is shown in **Fig. 6**. One key point of the invention is the implementation of signal cutoff functions at both ends of the steady ramp-up/ramp-down phase. Once the signal controlling the switching device leaves the steady transition phase, the signal condition is changed abrupt. **Fig. 7b** visualizes this effect. The purpose is to ~~overdrive~~ drive said switching device to a fully-on state, when said switching device operates outside its steady transition area on the low resistance side (low RDSon) of said switching device and, in a complementary way, to ~~overdrive~~ drive said switching device to a fully-off status, when said switching device leaves its steady transition area on the high resistance side (high RDSoff).

Please replace the last paragraph on page 11 with the following amended paragraph:

An even further method is to produce threshold levels along a non-linear curve, i.e. by not spreading ~~the~~ said threshold ~~points~~ levels with equal distances in order to get a desired non-linear relation of the total capacitance change versus tuning voltage.

In the DESCRIPTION OF THE PREFERRED EMBODIMENTS,
please add the following line

Fig. 7a shows the relation of a switching device's resistance RDS versus its gate voltage.

Please replace the following line

Fig. 7b visualizes said switching transistor's gate voltage versus capacitor tuning voltage dependency of a single stage.

And please replace the following line

Fig. 10a shows the additional circuits to provide the cutoff signals to ~~overdrive~~ drive the switching devices to a fully off or fully on state.

In the DESCRIPTION OF THE PREFERRED EMBODIMENTS,
please replace the last paragraph starting at page 16 with the following amended paragraph:

A single capacitor switching stage, as shown in **Fig. 5**, contains a circuit to control the switching operation **Switch-Ctrl** (also called hereafter the switch control circuit), a switching device **SW** and a small capacitor **Cap**. Said circuit to control the switching operation receives a signal, dependent on the tuning voltage **Vtune**, an input reference signal **Ref-in-5** and an output reference signal **Ref-out-5**, where said input reference signal **Ref-in-5** is then provided to the input reference point **Vinn-5** and said output reference signal **Ref-out-5** is then provided to the output reference point **Voutn-**

5. The translinear amplifier in **Fig. 5**, imbedded within said circuit to control the switching operation **Switch-Ctrl**, possibly together with some electronic glue components, compares the differential voltage at its inputs **Vinp-5** and **Vinn-5** and, through various current mirroring techniques~~,~~ and provides the same differential voltage at its outputs **Voutp-5** and **Voutn-5**; i.e. the output difference of said amplifier strictly follows the difference at said amplifier inputs, independent of the absolute voltage level at the outputs. Said switch control circuit **Switch-Ctrl** then provides a switch control signal **Vsw**, based on said~~The~~ translinear amplifier's output signal to said switching device **SW**. Switch control signal **Vsw** then drives ~~said~~ a current switching device **N1-5** with the gate voltage **Vg-5** to switch on said individual small capacitor **Cap-5** in the proposed steady ramp-up/ramp-down manner. Switching in said steady ramp-up/ramp-down manner results in the desired variable capacitance **Var-Cap-5** of said single capacitor switching stage.

Please replace the first paragraph starting at page 17 with the following two amended paragraphs; please note, the original paragraph is now split in two:

Each of said translinear amplifiers can operate at a different absolute voltage level at their input and work independent at another output level. In this way the network to generate the reference voltages can be optimized independently for each stage, because the voltage level best suitable for the control operation of each switching transistor can be freely selected. In the circuit shown in **Fig. 6** as an example, a reference circuit **RefCirc** individually provides the input and output reference voltages ~~are produced in a simple chain of resistors. The~~ to each of said switch control circuits

Switch-Ctrl with their imbedded translinear amplifiers **Tr.Amp 1** to **Tr.Amp n**, As described with Fig. 5, said translinear amplifiers can individally adjust between said input reference voltage levels **Ref-in 1** to **Ref-in n** and ~~the~~ said output reference levels **Ref-out-1** to **Ref-out-n**. Then each of s~~S~~aid translinear amplifiers ~~then~~ provides its signal to control the switching ~~transistors~~ devices **Sw 1** to **Sw n**, which in turn switch on the individual small capacitors **Cap 1** to **Cap n** in the proposed steady ramp-up/ramp-down manner. ~~The combination of one translinear amplifier **Tr.Amp k**, combined with adequate control circuit and one switching device **Sw k** could be considered as an individual capacitor switching stage, where one~~ Each of said capacitor switching stages connects to one capacitor **Cap k** out of a set of small capacitors. Each of said capacitor switching stages is controlled through the common input signal **Vtune** and an individual input reference **Ref-in k**. All of these stages k = 1 to n have basically identical functional characteristics.

(note: this paragraph is now split in two paragraphs)

In the same way as described in said related patent application US Serial No. 10/764920, within a set of small capacitors **Cap 1** to **Cap n**, one capacitor after the other is switched in parallel to change the total capacity. Each capacitor has its individual switching device **Sw 1** to **Sw n.** To achieve a linear capacitance change, said capacitors are not switched on one by one in digital steps, however each capacitor is switched on partially in a sliding operation, starting at low value (0 % of its capacitance) and ending with the fully switched on capacitor (100 % of its capacitance). To achieve said sliding switch operation, a typical implementation uses FET- type transistors, one per capacitor. The switching operation of such FET-transistor can be divided into three

phases: the fully-switched-off phase (the FET transistor's drain-source-resistance RDS is very high), a steady ramp-up/ramp-down phase or steady transition phase, where the series resistance of said FET-transistor linearly follows the gate voltage and steadily changes from high to low values or vice versa, and the fully-switched-on phase (said FET transistor's drain-source-resistance RDS is very low). **Fig. 10b** in US Patent Application Serial No. 10/764920, included by reference, visualizes the principal RDSon characteristic versus gate voltage of the switching devices **N1-5** of a single capacitor switching stage according to **Fig. 5** of the present application. By thoroughly controlling such switching device within said steady ramp-up/ramp-down or steady transition area, the capacitor in series with said switching device is effectively switched in parallel to the other capacitors with a well-controlled proportion between 0 % and 100 %. "Steady" is meant in the mathematical sense of being free of jumps or breaks. The limits of said steady ramp-up/ramp-down or steady transition area is distinguished by the points, where a further change of the controlling signal of the switch does not lead to further decrease or increase of the series resistance of said switching device (except for a small, negligible change).

Please replace the last paragraph starting at page 18 and continuing to page 19 with the following amended paragraph:

In case a specific member of said switching devices, as shown in **Fig. 6**, is switched fully-on, the parallel connection of the capacitor (in series with said switching device in view) is fully effective (i.e. is effective to 100 %). If however a specific item of said switching devices is switched fully-off, the parallel connection of the capacitor (in series with said switching device in view) is not effective at all (i.e. is effective to 0 %). While said switching device in view is operating within its steady ramp-up/ramp-down or

steady transition phase, the capacitor may be effectively switched in parallel with any value between 0 % and 100 %. The effectiveness of the switching in parallel of said capacitor is well controlled through the translinear amplifiers **Tr.Amp 1** to **Tr.Amp n** and the relation of tuning and reference voltages, ~~symbolized by the voltage dividing circuit of the resistor chain **R1** to **Rn**~~ according to the input reference levels provided by the reference circuit **RefCirc**. One can assume the steady transition area of RDS changing to be, for example, between the 2 % point and the 98 % point and define these limits as the ~~"~~desired end points of the steady transition area~~"~~. Close to these end points, the linear operation of real switching devices come to a natural end.

Please replace the last paragraph starting at page 19 and continuing to page 20 with the following amended paragraph:

~~Outside said "steady transition area" the switching device is not operating in a virtual linear mode any more, for example because it is reaching a switching transistor's saturation. The term "outside the steady transition area" therefore defines the capacitor switching stage's operating area outside its virtually linear "steady transition area".~~ The linear operation of real switching devices is naturally limited, for example because it is reaching a switching transistor's saturation or because the resistance already reached the maximum achievable value and where, for example, a further change of gate voltage **Vg** would not create further increase of a switching transistor's resistance RDS. As explained before, the area of linear operation is called the "steady transition area", consequently the areas beyond the linear operating area are named here as the areas "outside the steady transition area". These are the areas where further change of the switch control signal **Vsw** would first cause only a non-linear change of resistance RDS and would finally have no more effect. In **Fig. 7a** the ~~different~~ linear operating area~~s~~ and

its end-points ~~are~~ is shown: the **Steady** ~~**ramp-up/ramp-down**~~ **Transition Area**, the ~~areas outside~~ end-point of the steady transition area ~~**Outside Lo**~~ at the low (RDS) resistance side of said switching device, marked **Ep-Lo**, and the end-point of the steady transition area ~~**Outside Hi**~~ at the high (RDS) resistance side of said switching device, marked **EP-Hi**. ~~The cutoff edges are marked with **CutOff Lo** and **CutOff Hi**.~~ The switching device to switch on the capacitor~~,~~ ~~as~~ is used for the presented patent application~~,~~ ~~is~~ as a "switching device with a well controllable steady ramp-up/ramp-down area "; said device is in many cases shortly referenced in the instant document as "switching device".

Please replace 4 paragraphs, starting with the last paragraph at page 21 and continuing through the last paragraph on page 22 with the following 4 amended paragraphs:

There are various techniques for a circuit to generate a set of input and output reference values and to provide the threshold levels to each of said capacitor switching stages. And there are various techniques ~~for a circuit~~ to provide a suitable input signal, dependent on the tuning voltage, dedicated for the voltage controlled capacitance change, to all of said capacitor switching stages. A conceptual circuit diagram for providing said input reference levels **Ref-in 1** to **Ref-in n** and said output reference levels **Ref-out 1** to **Ref-out n** is shown in **Fig. 6**. As shown in ~~**Fig. 6** and~~ **Fig. 9**, one solution for said circuit to generate a set of input reference values is a simple resistor chain. A possible and minimal, though not the only, solution for a circuit to provide the input threshold levels **Ref-in n** ~~to each of said capacitor switching stages~~ and similarly ~~for a circuit~~ to provide ~~a signal, dependent on~~ the tuning voltage **Vtune** ~~and dedicated~~

~~for the voltage controlled capacitance change~~, ~~to all of said capacitor~~ from inputs of said switching ~~stages~~ control circuit **Switch-Ctrl** to the therin embedded translinear amplifier, is to connect said individual threshold levels, as well as said tuning voltage, with simple wire connections to the appropriate input lines of said translinear amplifiers, that is without using further intermittent electronic glue components, as anticipated inside said switching control circuit **Switch-Ctrl** in **Fig. 5** and **Fig. 6**.

Similar~~ly~~ to the input reference levels in **Fig. 9**, the output reference levels could be provided for example through a resistor network to provide individual output reference levels for each translinear amplifier (**Ref-out-1** to **Ref-out-n** ~~in **Fig. 6**~~). ~~Or,~~ A possible and minimal solution to provide the identical output reference level to all translinear amplifiers, could be to connect a single signal ~~could be connected~~ to all ~~inputs~~ output reference points ~~**Ref-out-1 to Ref-out-n**~~ of all translinear amplifiers (~~as indicated~~equivalent to **Ref-out-1** to **Ref-out-n** in **Fig. 6**) to a common output reference level **C-Ref-out**, as it is shown in **Fig. 9**.

Another key point of the invention is the implementation of signal cutoff functions at both ends of the steady ramp-up/ramp-down area. ~~As long as the switching transistor is kept within its natural steady transition phase (RDS steady changing mode) the resistance of the transistor linearly follows the input difference of said translinear amplifier. Once the signal controlling the switching device leaves the desired steady transition area, the signal condition is now changed abrupt by one of the signal cutoff circuits. **Fig. 7** visualizes this effect. The purpose is to overdrive said switching device to a fully-on state, when said switching device operates outside its desired steady transition area on the low resistance side and to overdrive said switching device to a~~

~~fully-off status, when said switching device leaves its steady transition area on the high resistance side.~~ At the end-points of said steady transition area, where further linear change of the switch control signal **Vsw** would have nearly no further effect on the switching device to change its resistance RDS. After passing said end-points of said steady transition area, it would be desirable to not continue with a linear signal to control the switching device, but to apply a very steep signal change, thus driving the switching device very sharply into its minimum achievable resistance (RDSon as low as possible) or into its maximum achievable resistance (RDSoff as high as possible). Two additional circuits, **CutOffC-Lo** and **CutOffC-Hi** in **Fig. 10a**, perform said steep signal change, where one of said two additional circuits takes over full control of the switch control signal **Vsw**, i.e. they "override" the normal control signal, as provided by the translinear amplifier itself. The end-points of said steady transition area, where the steep signal change should appear are called the cut-off edges. Which of said two additional circuits is activated, depends on the switch status: to drive the switching device into minimum achievable resistance (RDSon as low as possible), the additional cut-off circuit **CutOffC-Lo** will be activated, or to drive the switching device into its maximum achievable resistance (RDSoff as high as possible) the additional cut-off circuit **CutOffC-HI** will be activated

Fig. 7b of the instant document visualizes the idea of sharply cutting off said signal controlling the switching device as soon as a changing Gate Control Voltage **Vg** leaves the desired steady transition area **Steady ramp-up/ramp-down Area** at the cutoff edges **CutOff Lo** and **CutOff Hi**. For example, at the two desired points, beyond the 98 % on-point, said signal **Vg** controlling the switching device is rised sharply and below the 2 % on-point said signal **Vg** controlling the switching device is driven to

rapidly switch-off. The area outside the desired steady transition area at the low (RDSon) resistance side of said switching device is marked **Outside Lo**, and the area outside the desired steady transition area at the high (RDSoff) resistance side of said switching device is marked **Outside Hi**. The end-points **Ep-Lo** and **Ep-Hi** in **Fig. 7a** correspond with the cutoff edges marked with **CutOff Lo** and **CutOff Hi**

Please erase the first full paragraph starting at page 23 as follows:

~~Additional circuit elements, implementing said signal cutoff functions, drive said switching transistor either into deep saturation (RDSon going to 0) or drive it into its extreme off state (RDSoff going very high) as soon as said switching device falls outside said desired steady ramp-up/ramp-down area.~~

Please replace 4 paragraphs, starting with the 2nd full paragraph at page 23 and continuing to the 2nd full paragraph on page 24 with the following 3 amended paragraphs:

A possible solution for said signal cutoff functions could be to implement said signal cutoff functions as separate circuits in combination with, but external to said translinear amplifier. The principal concept of said two separate circuits for said signal cutoff functions is shown in **Fig. 10a**, ~~. Switching devices **N3-10** and **N4-10** symbolize two circuits to drive said switching device to a fully on or fully off state, when said switching device operates outside said steady ramp-up/ramp-down area on the said switching device's low resistance side or high resistance side.~~ with the two signal cut-off circuits **CutOffC-Lo** and **CutOffC-Hi** added to said (main) circuit to control the switching operation **Switch-Ctrl** of **Fig. 5**. These three circuits then operate together (possibly similar in function to a dotted-OR connection of said three circuits) to provide a

combined control signal **Csw** for said switching device **SW**; Each cut-off circuit can thus override the output of the normal **Switch-Ctrl** circuit, once the switching device **SW** leaves the desired steady ramp-up/ramp-down area. Appropriate threshold elements will define the limits **CutOff Lo** and **CutOff Hi** of the steady ramp-up/ramp-down area, as shown in **Fig. 7b** and as explained above. Said possible threshold elements then provide ~~T~~the two control signals to either force said fully on or fully off state are **CtlCutOff Lo** and **CtlCutOff Hi**.

Another possible solution could be to implement said signal cutoff functions within said translinear amplifier circuit. Such solution integrated into the translinear amplifier is presented in Patent Application US Serial No. 10/676919, filed Oct. 1, 2003, which is hereby incorporated by reference. The relevant additional signal cutoff function is presented there on page 6, 3rd and 4th paragraph, on page 14, 1st and 2nd paragraph, page 15 2nd full paragraph, on page 17, 1st and 2nd paragraph and in **Fig. 7** with the additional circuits **ADD-COMP 1-7** and **ADD-COMP 2-7**. Circuit **ADD-COMP 2-7** in the referenced companion application is a real implementation of a cut-off circuit ~~element~~ ~~**N4-10**~~ **CutOffC-Lo** in **Fig. 10a** of the instant application and circuit **ADD-COMP 1-7** in the referenced companion application provides the control signal defined as **CtlCutOff Lo** in the instant application. The referenced application describes the implementation of the signal cutoff functions as cited in the following paragraph:

The envisioned solution is described in the first full paragraph on page 14 in the referenced Patent Application US Serial No. 10/676919 (and paragraph [0043] in the new issued Patent:) "According to said second aspect, two additional circuit functions sharply limit the analog operating region through an extra current limiting transistor on

one side and the purposely use of the voltage limited by the power supply on the other side. Key objective is to linearly control said translinear amplifier's output, for example for switching on or off a transistor in an application like it is shown in **Fig. 4** (of the referenced patent application), and getting sharp cutoff edges, for example for switching on or off a transistor in said application to achieve minimum RDSon and maximum of RDSoff at the extreme ends. The desired output characteristic is visualized in **Fig. 5** (of the referenced patent application)."

Please erase the last paragraph at page 24 and the first paragraph at page 25 as follows:

~~In **Fig. 5** of the referenced application and described there on page 15, 2nd full paragraph, the linear operating region on line **50b** is marked as the area **59**. Once either output **Vout-p** or **Vout-n** reaches the cutoff voltage **Vlim** at point **59a** or when it reaches the power supply line **Vdd** at point **59b**, the linear operation is sharply cut off.~~

~~The above cited linear operating region marked as the area **59**, is the same as the steady ramp-up/ramp-down area of the instant application.~~

Please add two paragraphs after the just erased first paragraph at page 25 as follows:

Further explanation of the additional circuit is found in the first paragraph on page 17 in the referenced Patent Application US Serial No. 10/676919 (and paragraph [0051] in the now issued Patent): "**Fig. 7** (of the referenced patent application) shows the circuit of **Fig. 6** with the additional limiting transistor function, where the additional

components are shown inside the dashed frames, marked with **ADD-COMP 1-7** and **ADD-COMP 2-7**. According to said second aspect of this invention, two additional circuit functions sharply limit the analog operating region through an extra current limiting transistor on one side and the purposely use of the voltage limited by the power supply on the other side. Transistor **N13-7** incorporates said current limiting transistor. (.....) As soon as the current drawn by **N13-7** exceeds the current provided by **N8-7**, **N13-7** sinks all available current and the output is cut-off."

And even further in the second paragraph on page 17 in the referenced Patent Application (and paragraph [0052] in the now issued Patent): "Similar, when the output voltage **Voutp-7** swings to **Vdd**, further voltage increase is suddenly impossible, thus sharply limiting said linear operation region" in the desired way.

Please replace the 2nd paragraph at page 25 with the following amended paragraph:

The specific implementation of the signal cutoff function integrated within said translinear amplifier of the referenced application takes advantage of the fact, that the output signal can completely swing up to the power supply rail, driving the Gate-Source Voltage of the switching device to zero, thus forcing a PMOS switch to go into high impedance state without any further measures. In ~~the~~ case the output signal could not swing up to the power supply rail or if a different type of switching device is used, an additional circuit similar in function to the circuits **ADD-COMP 1-7** and **ADD-COMP 2** would be implemented.

Please replace 3 paragraphs, starting with the last full paragraph at page 25 and continuing to the last paragraph on page 26 with the following 4 amended paragraphs:

Fig. 8 presents the same behavior as **Fig. 7b** for a larger number of said capacitor switching stages. **Th1** to **Thn** are the selected threshold for said switching to occur. **d1** to **dn** are the distances of said threshold, that normally are dimensioned to equal distance. The capactitor tuning voltage **Tuning Voltage Vctl** is supplied to all capacitor switching stages as a common signal.

Fig. 9 shows a realistic circuit diagram of an implementation, in accordance with an embodiment of this invention. **Tr.Amp 1** to **Tr.Amp n** are said translinear amplifiers, **Sw 1** to **Sw n** are the switching devices and **Cap 1** to **Cap n** are said capacitors that will be switched in parallel, resulting in the total capacitance **varCap**. **R1** to **Rn** build the resistor chain to produce references voltages for the amplifier of each stage, as ~~already~~ an implementation of the reference circuit shown in **Fig. 6**. Similar to Fig. ~~7~~6, the combination of one translinear amplifier **Tr.Amp k**, combined with adequate control circuit and one switching device **Sw k** could be considered as an individual capacitor switching stage, where one of said capacitor switching stages connects to one capacitor **Cap k** out of a set of small capacitors. Each of said capacitor switching stages is controlled through the common input **Vtune** and an individual input reference level **Ref-in k**. In the implementation shown in **Fig. 9**, the output reference ~~points~~signals **Ref-out k** of **Fig. 6** are all connected to a common output ~~R~~reference ~~point~~signal ~~**Vref.**~~ **C-Ref-out**. All of these stages k = 1 to n have basically identical functional characteristics.

Furthermore, a concept of this disclosure is to compensate the temperature deviation, caused by the temperature characteristics of the switching device; **Fig. 10b**

presents this concept, which shows a temperature compensating circuit **Temp-Comp** in addition to said circuit to control the switching operation **Switch-Ctrl**, as shown in **Fig. 5**. One method is to use a device **N2-10** of the identical type of the switching device **N1-10** to produce a temperature dependent signal and feed it as compensating voltage **Vref-10** into the output reference point **Voutn-10** of the translinear amplifier. This will mirror the exact equivalent of the temperature error into the switching control signal **Vg-10** and compensate its temperature error. The output reference point **Voutn-10** in **Fig. 10b** is the same point as the reference ~~points~~signals **Ref-out** ~~1 to **Ref-out n**~~ in **Fig. ~~6~~5**.

(one additional line-feed; this paragraph is now split in two paragraphs)

The total capacitance versus tuning voltage characteristic for a circuit with n-stages is demonstrated in **Fig. 11a** and the overall characteristic of said Q-factor is presented in **Fig. 11b**.